# Differentiable Appearance Acquisition from a Flash/No-flash RGB-D Pair

## Supplement Material

Hyun Jin Ku[†]     Hyunho Ha[†]     Joo Ho Lee[†,*]     Dahyun Kang[†]
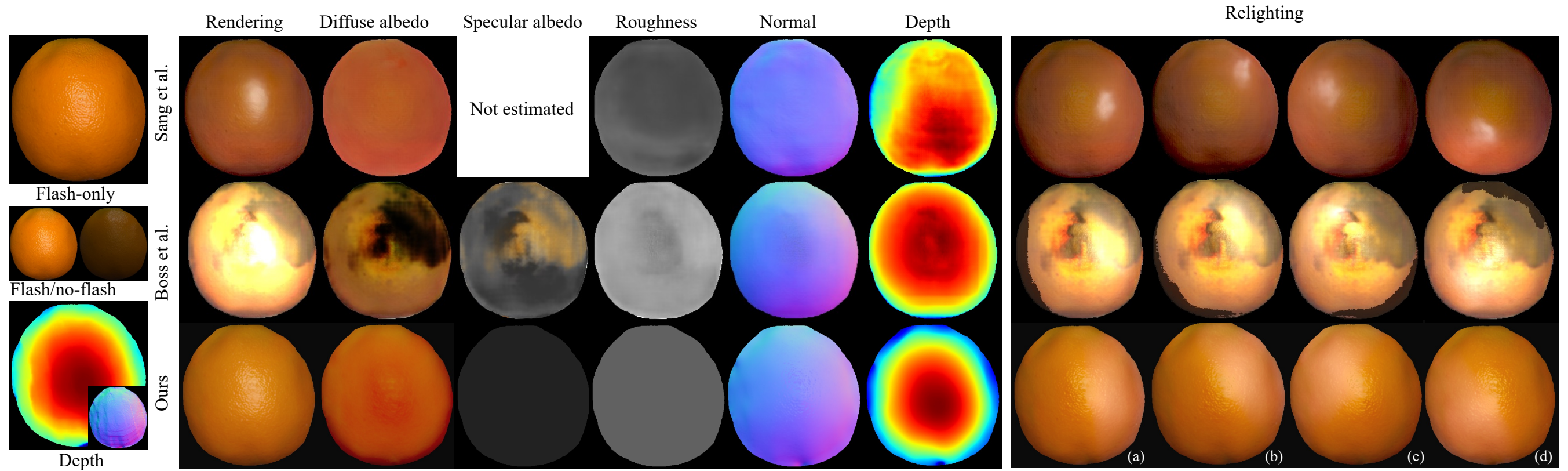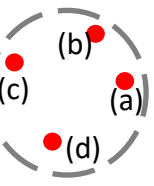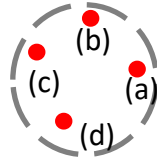James Tompkin[§]     Min H. Kim[†]

[†] KAIST          [*] Sogang University          [§] Brown University

# Real-world objects

# Orange



Flash-only

Flash/no-flash

Depth

Sang et al. — Rendering, Diffuse albedo, Specular albedo (Not estimated), Roughness, Normal, Depth

Boss et al.

Ours

Relighting

(a) (b) (c) (d)

# Chicken



| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth | | Relighting | | |

# Santa



| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth | Relighting |
|---|---|---|---|---|---|---|---|
| Sang et al. | | | Not estimated | | | | |
| Boss et al. | | | | | | | |
| Ours | | | | | | | |

Flash-only

Flash/no-flash

Depth

(a) (b) (c) (d)

# Owls
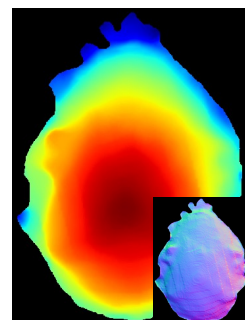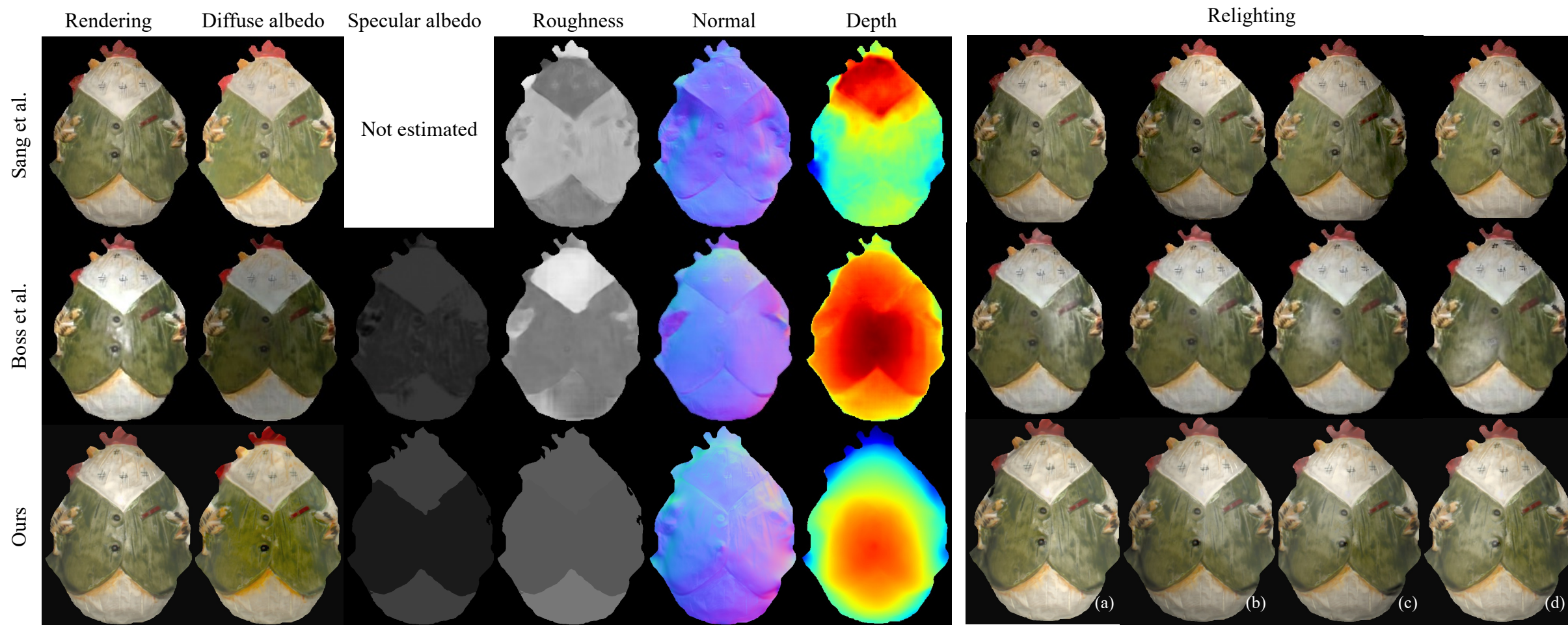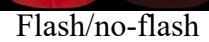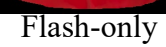


Flash-only

Flash/no-flash

Depth

Sang et al.

Boss et al.

Ours

Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth | Relighting
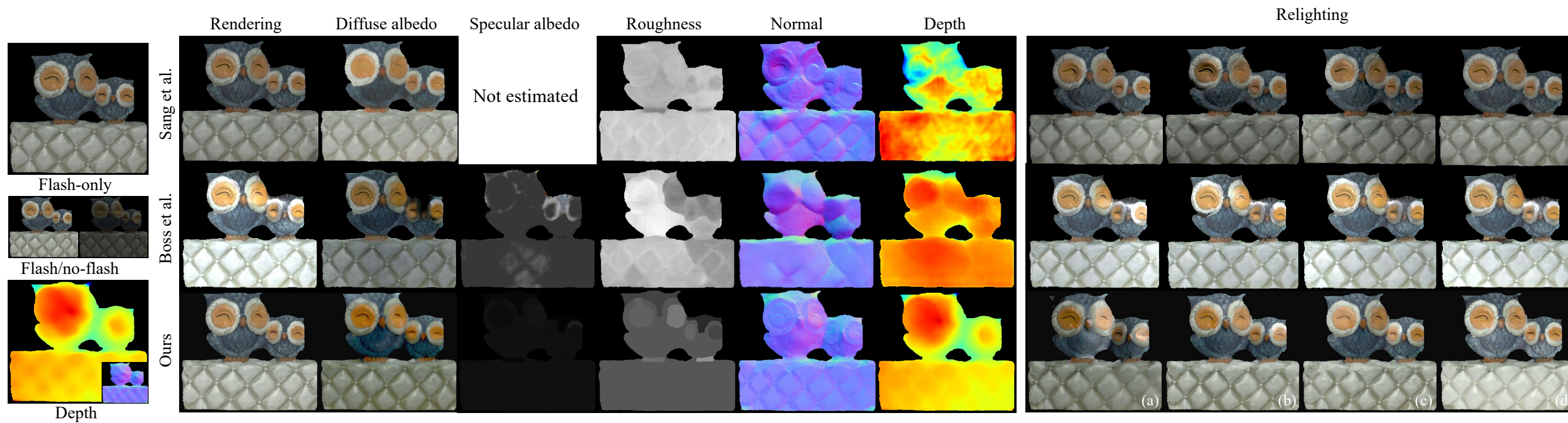
Not estimated

(a) (b) (c) (d)

# Rugby (Mobile phone data)



Flash-only

Flash/no-flash

Depth

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth | Relighting |
|---|---|---|---|---|---|---|---|
| Sang et al. | | | Not estimated | | | | |
| Boss et al. | | | | | | | |
| Ours | | | | | | | (a) (b) (c) (d) |

Synthetic dataset

Rendering   Diffuse albedo   Specular albedo   Roughness   Normal   Depth ($\times 10^{-4}$)   Relighting

Flash-only

Flash/no-flash

Depth

GT

Sang et al.

Not estimated

0.000   0.002   0.004*   0.258   12.31

Boss et al.

0.028   0.003   0.002*   0.002*   0.177   2.61

Ours

0.001   0.004   0.002*   0.002*   0.164   0.05

(a)   (b)   (c)   (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

GT

Flash-only

Flash/no-flash

Depth

Sang et al.    0.000    0.002    Not estimated    0.006*    0.437    43.22

Boss et al.    0.037    0.010    0.021*    0.021*    0.261    3.55

Ours    0.001    0.006    0.003*    0.003*    0.192    0.27

(a)    (b)    (c)    (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

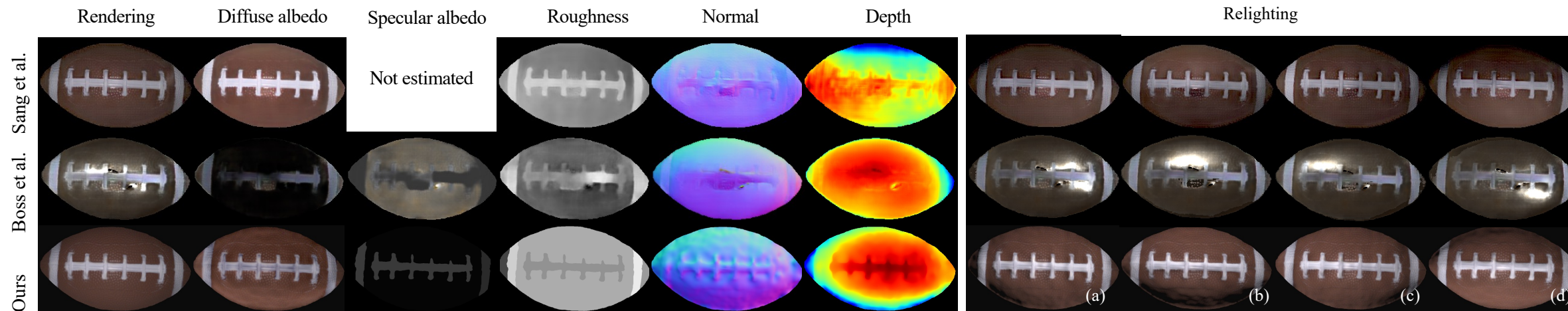| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | | Relighting | | |
|---|---|---|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.

Not estimated

0.000 · 0.001 · 0.004* · 0.630 · 70.62

Boss et al.

0.007 · 0.001 · 0.002* · 0.002* · 0.256 · 8.09

Ours

0.000 · 0.005 · 0.002* · 0.002* · 0.149 · 0.38

(a) (b) (c) (d)

\*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

Flash-only

Flash/no-flash

Depth

|  | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

GT

Sang et al. | 0.001 | 0.027 | Not estimated | 0.044* | 0.342 | 11.29 |

Boss et al. | 1.174 | 0.044 | 1.455* | 1.455* | 0.371 | 36.25 |

Ours | 0.000 | 0.038 | 0.025* | 0.025* | 0.174 | 0.24 |

(a)    (b)    (c)    (d)

NB As Boss et al. model the Fresnel term from colored illumiNot estimatedtion, three-channel specular albedo is used for Boss et al. In contrast, Sang et al. and ours model monochromatic specular albedo from illumiNot estimatedtion, single-channel specular albedo is employed for both methods.
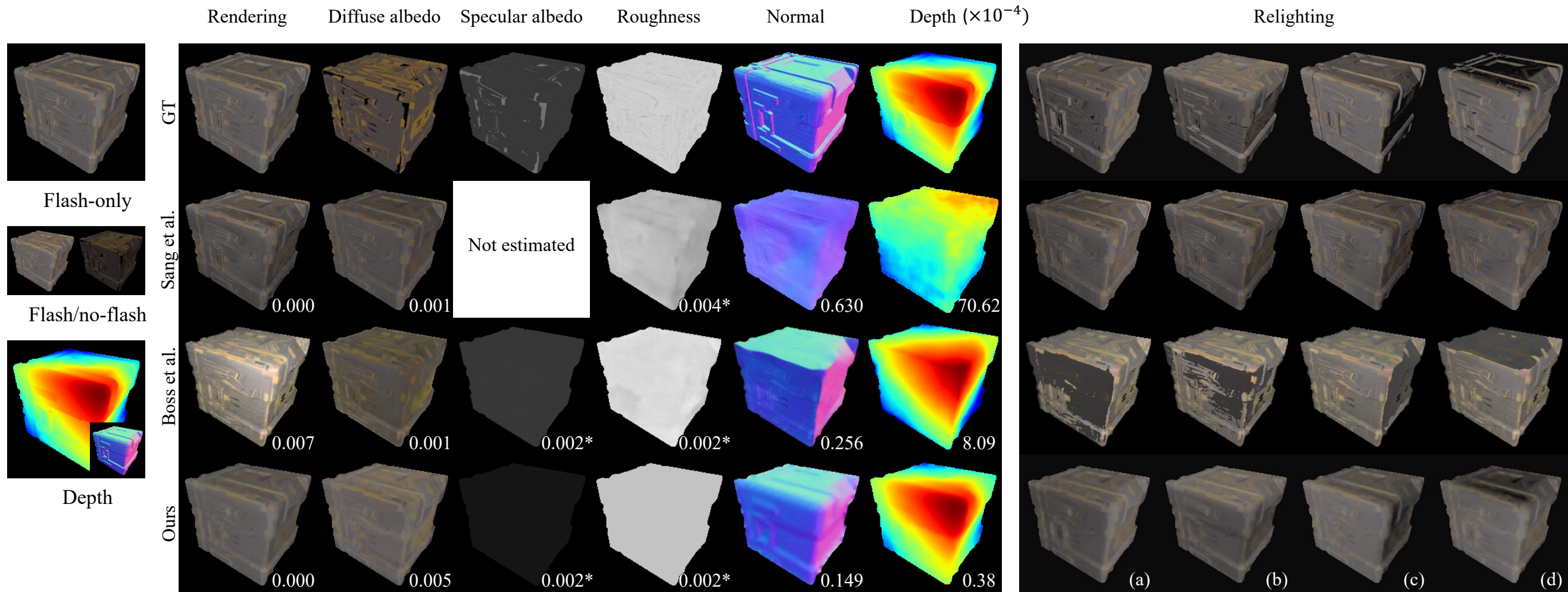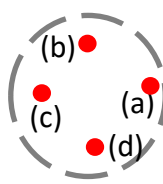
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.
0.000 — 0.001 — Not estimated — 0.005* — 0.924 — 50.94

Boss et al.
0.078 — 0.003 — 0.010* — 0.010* — 0.569 — 35.15
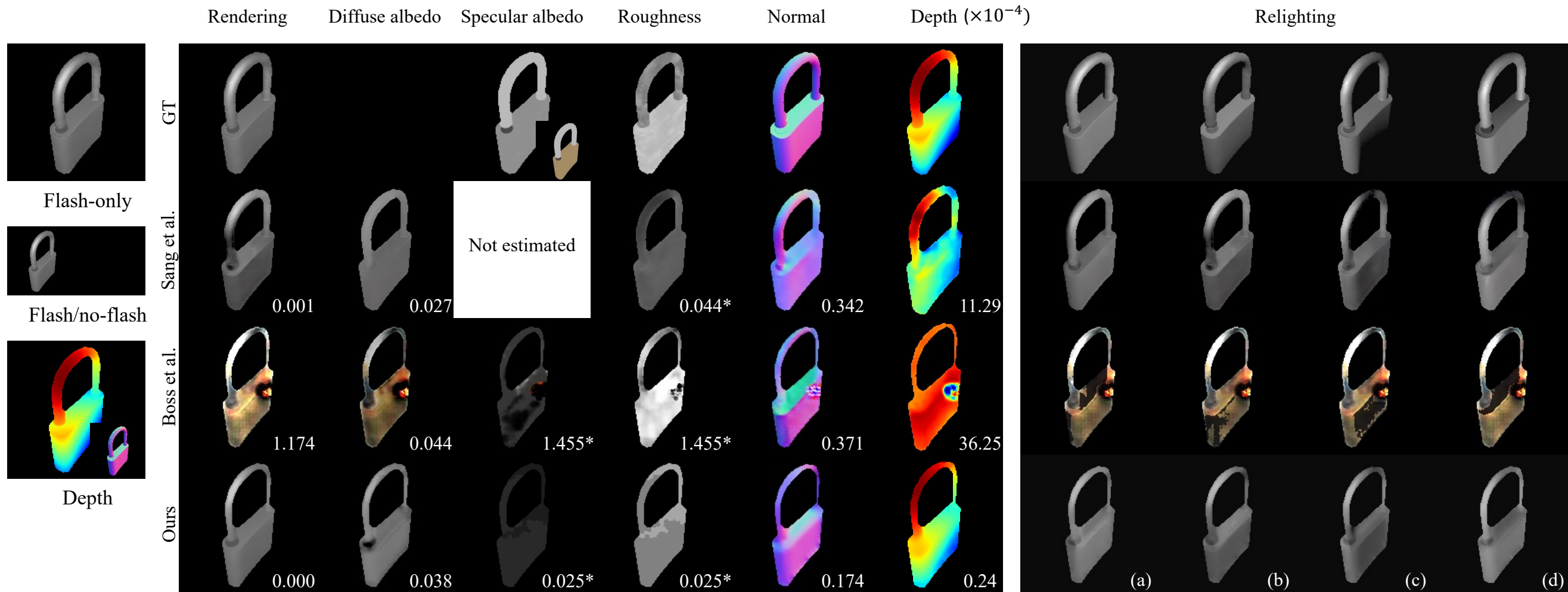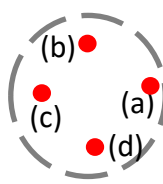
Ours
0.000 — 0.007 — 0.005* — 0.005* — 0.332 — 15.48

(a) (b) (c) (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | | Relighting | | |
|---|---|---|---|---|---|---|---|---|---|---|

GT

Sang et al.
Not estimated
0.001    0.002    0.014*    0.459    133.87

Boss et al.
0.051    0.002    0.054*    0.054*    0.274    52.23

Ours
0.000    0.022    0.012*    0.012*    0.093    2.38

(a)    (b)    (c)    (d)
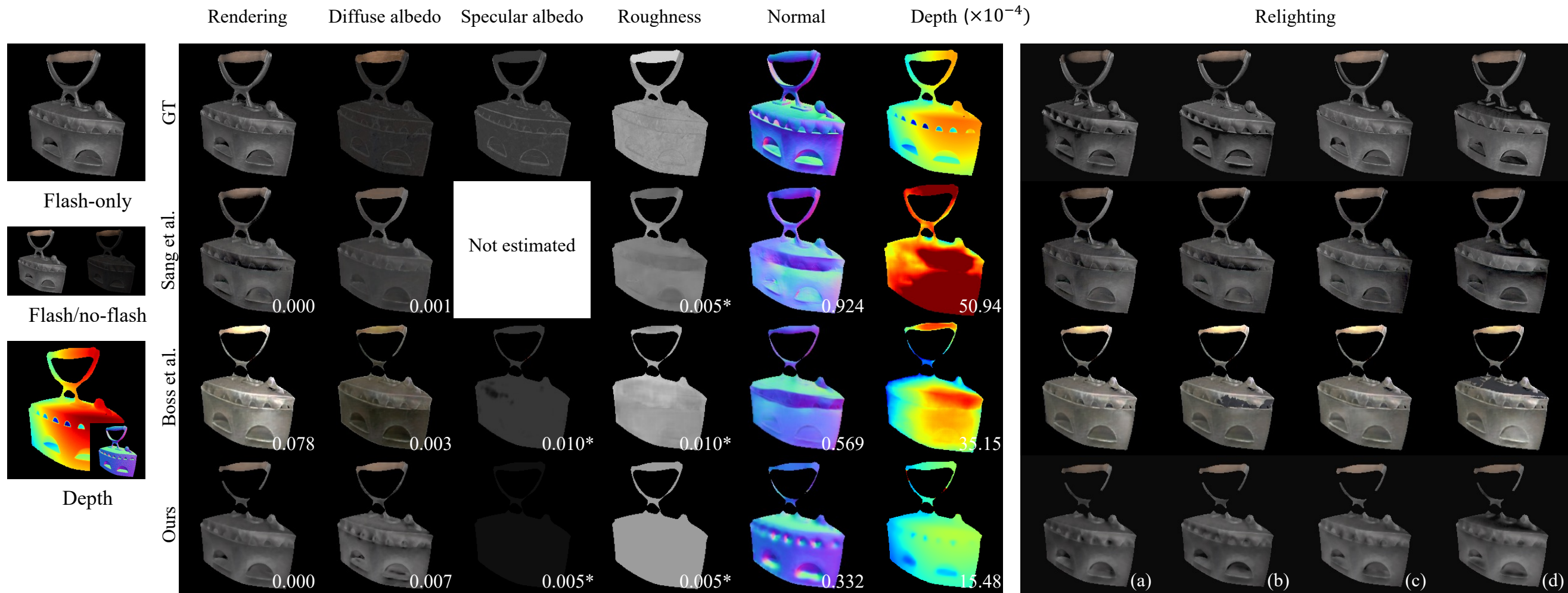
Flash-only

Flash/no-flash

Depth

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

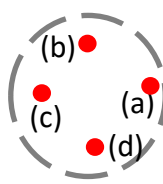| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|

GT

Flash-only

Flash/no-flash

Depth

Sang et al.

Not estimated

0.000     0.002     0.009*     0.863     88.24

Boss et al.

0.025     0.002     0.038*     0.038*     0.252     15.57

Ours

0.001     0.017     0.008*     0.008*     0.217     0.05
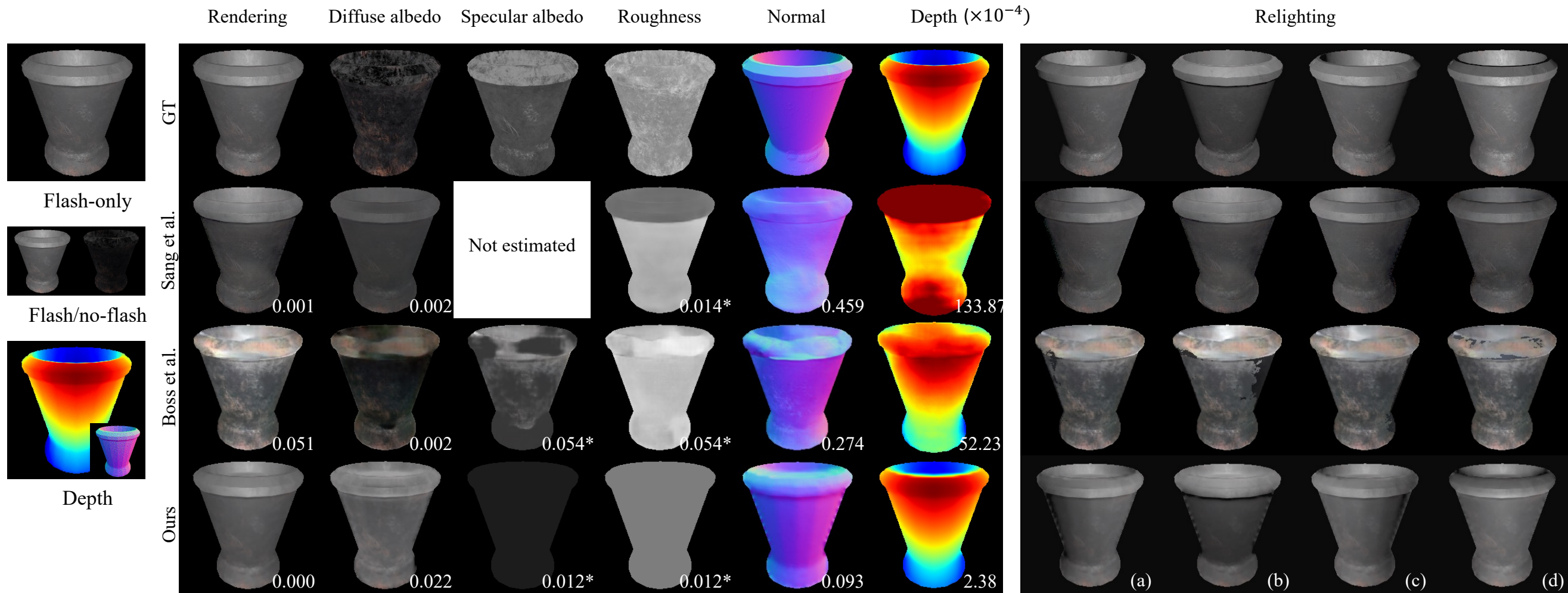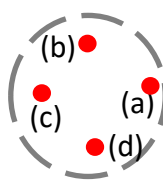
(a)     (b)     (c)     (d)

NB As Boss et al. model the Fresnel term from colored illumiNot estimatedtion, three-channel specular albedo is used for Boss et al. In contrast, Sang et al. and ours model monochromatic specular albedo from illumiNot estimatedtion, single-channel specular albedo is employed for both methods.
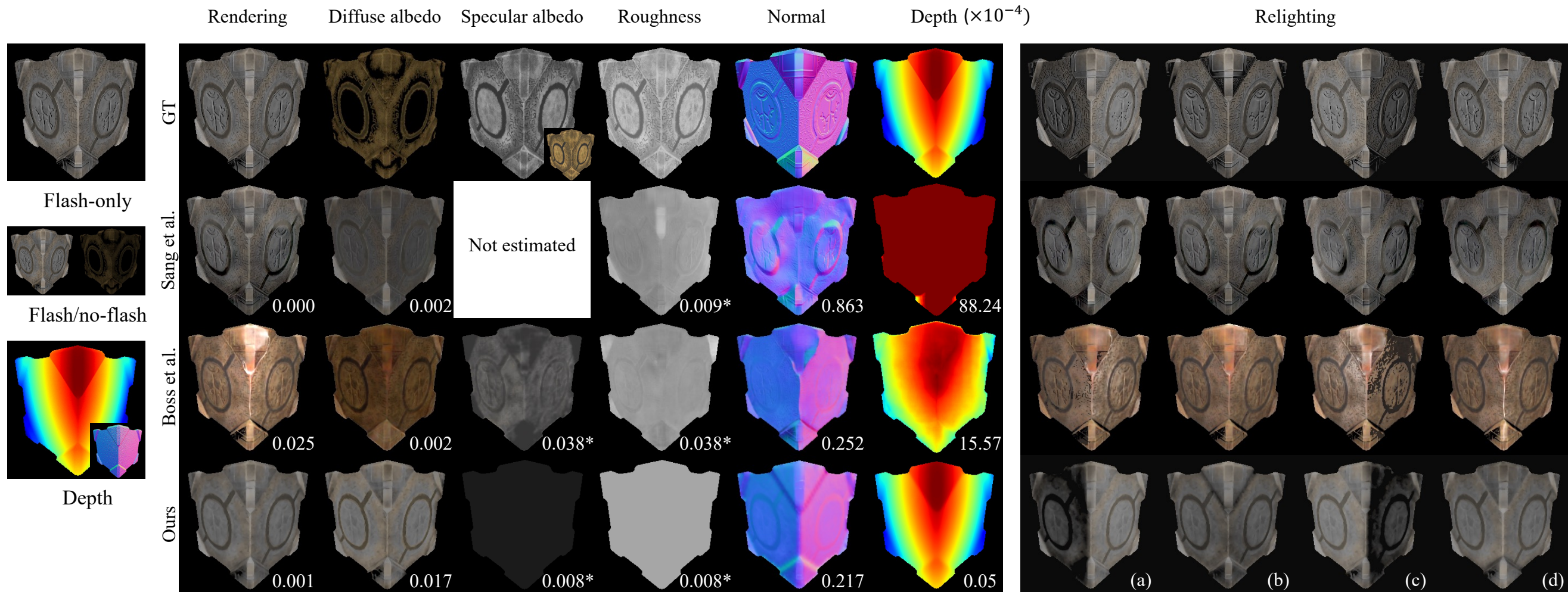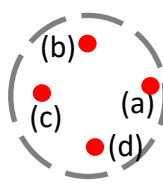
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

Flash-only

Flash/no-flash

Depth

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | | Relighting | | |
|---|---|---|---|---|---|---|---|---|---|---|

GT

Sang et al.

Boss et al.

Ours

|  | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) |
|---|---|---|---|---|---|---|
| Sang et al. | 0.013 | 0.007 | Not estimated | 0.059* | 0.417 | 29.32 |
| Boss et al. | 0.095 | 0.008 | 0.164* | 0.164* | 0.439 | 28.74 |
| Ours | 0.000 | 0.056 | 0.037* | 0.037* | 0.106 | 1.69 |

(a)   (b)   (c)   (d)

NB As Boss et al. model the Fresnel term from colored illumiNot estimatedtion, three-channel specular albedo is used for Boss et al. In contrast, Sang et al. and ours model monochromatic specular albedo from illumiNot estimatedtion, single-channel specular albedo is employed for both methods.
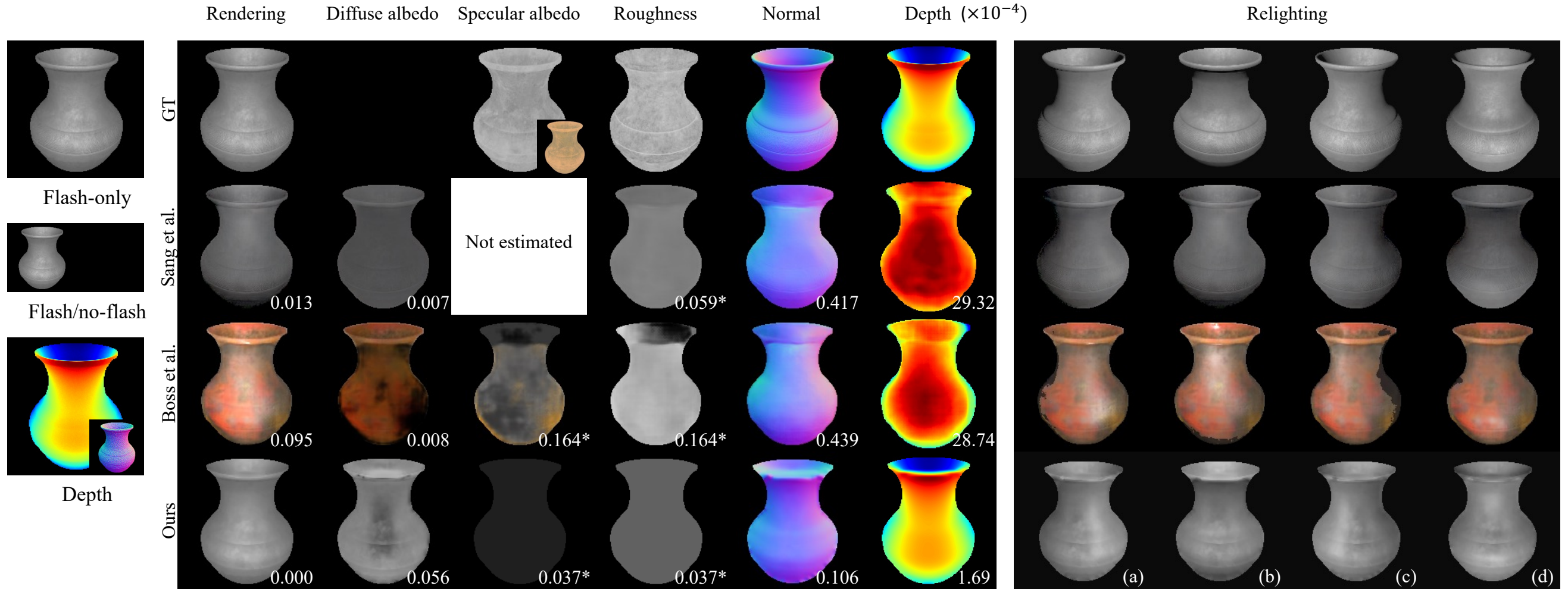
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

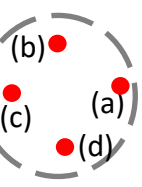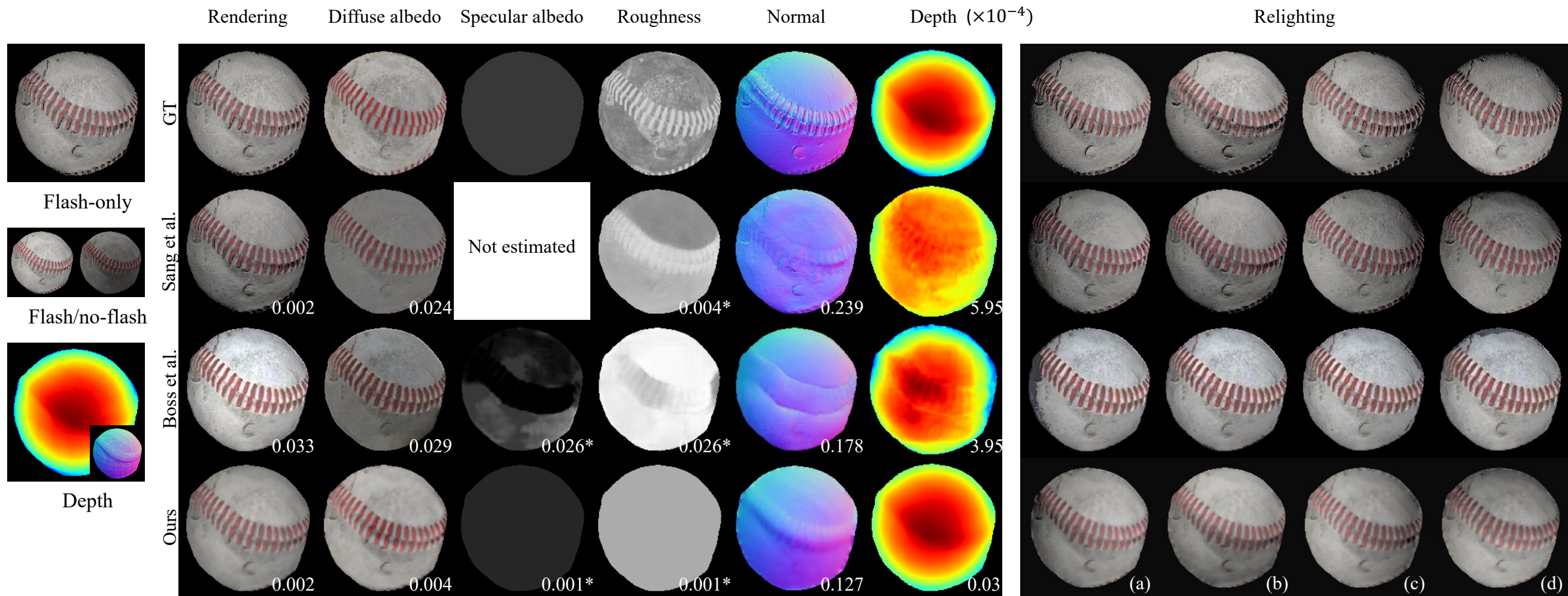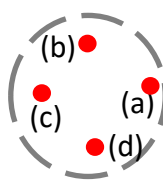|  | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.
0.002   0.024   Not estimated   0.004*   0.239   5.95

Boss et al.
0.033   0.029   0.026*   0.026*   0.178   3.95

Ours
0.002   0.004   0.001*   0.001*   0.127   0.03

(a)   (b)   (c)   (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

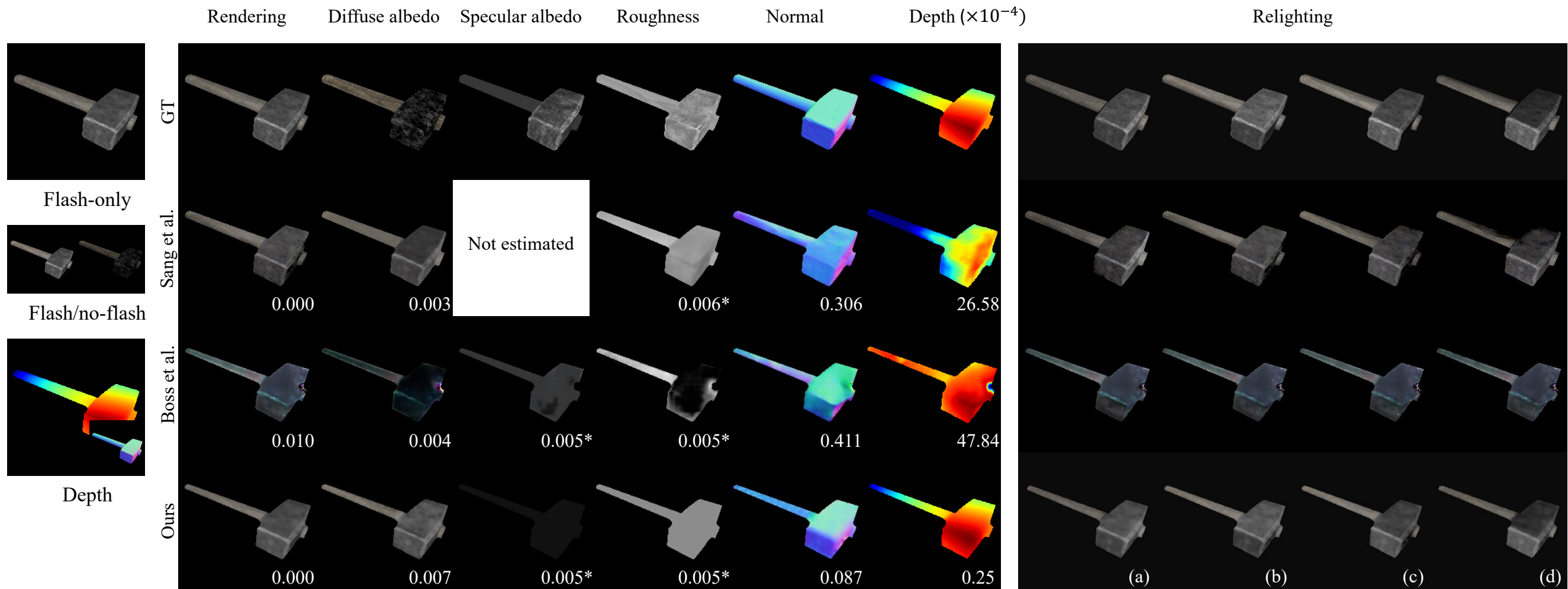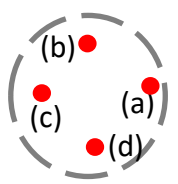| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|

**Flash-only**

**Flash/no-flash**

**Depth**

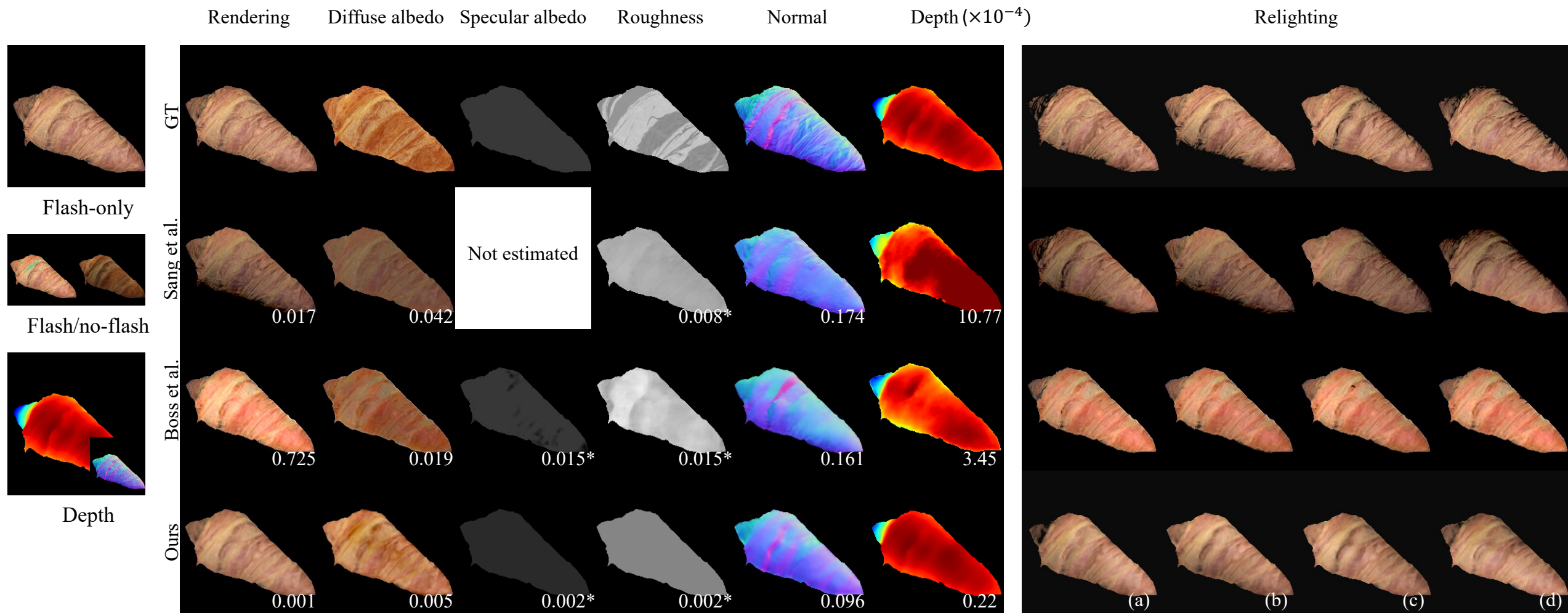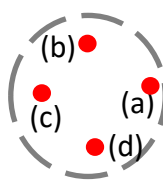| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth |
|---|---|---|---|---|---|---|
| **GT** | | | | | | |
| **Sang et al.** | 0.017 | 0.042 | Not estimated | 0.008* | 0.174 | 10.77 |
| **Boss et al.** | 0.725 | 0.019 | 0.015* | 0.015* | 0.161 | 3.45 |
| **Ours** | 0.001 | 0.005 | 0.002* | 0.002* | 0.096 | 0.22 |

(a)  (b)  (c)  (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

Flash-only

Flash/no-flash

Depth

Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | Relighting

GT

Sang et al.

Not estimated

0.006 | 0.024 | | 0.013* | 0.446 | 60.82

Boss et al.

0.348 | 0.038 | 0.176* | 0.176* | 0.353 | 31.62

Ours

0.001 | 0.017 | 0.007* | 0.007* | 0.232 | 1.89
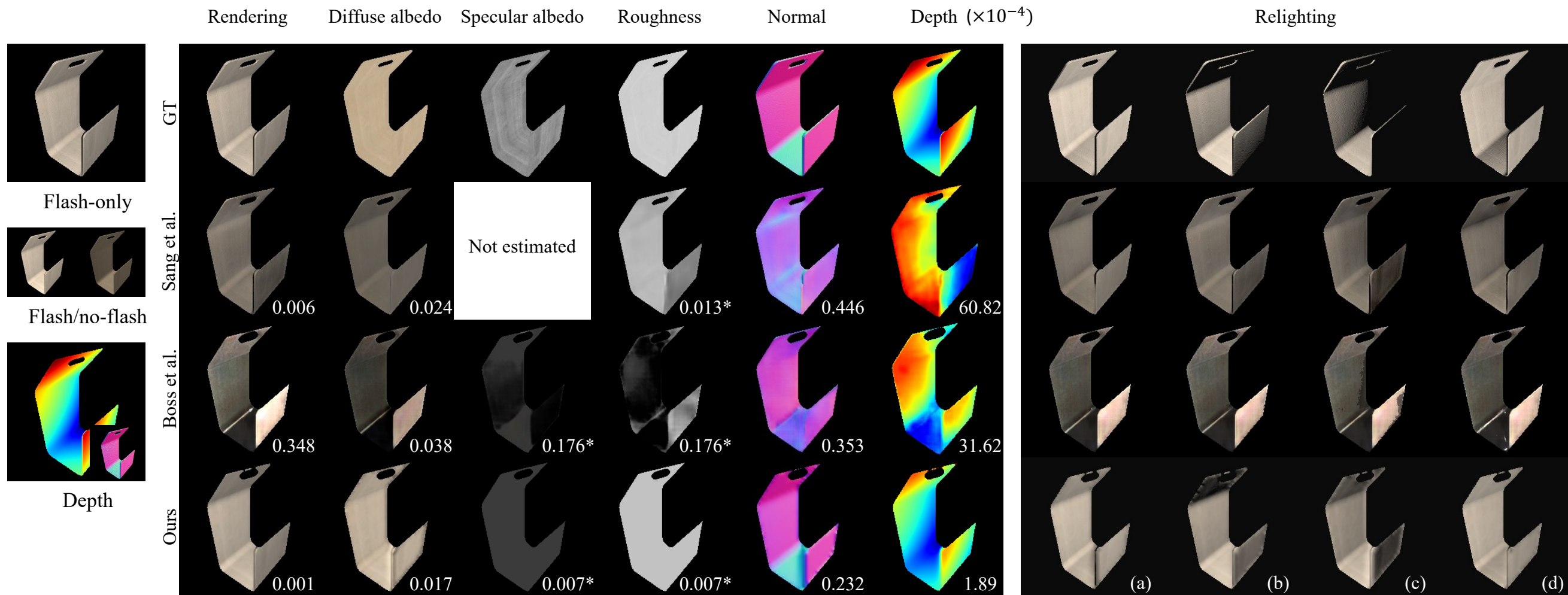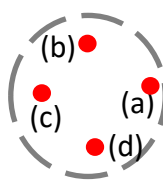
(a)    (b)    (c)    (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.
Not estimated
0.021    0.050    0.005*    0.148    12.26

Boss et al.
1.473    0.058    0.020*    0.020*    0.162    3.74

Ours
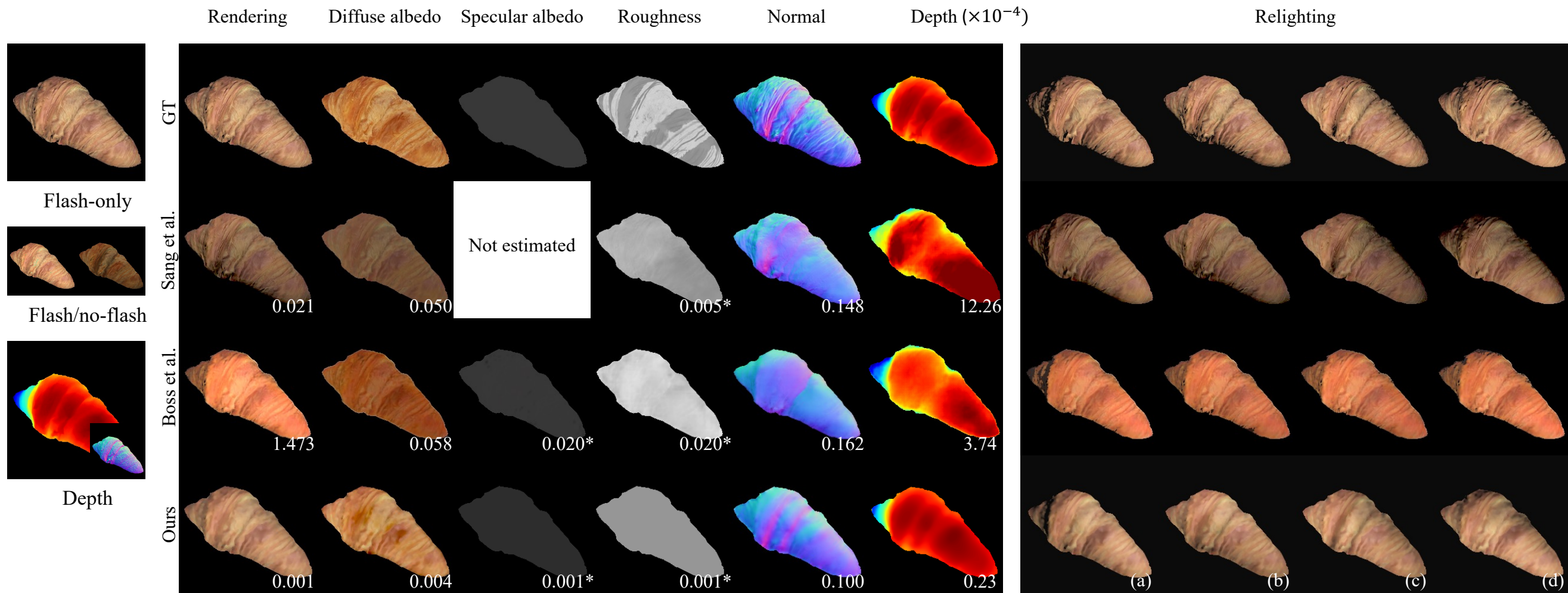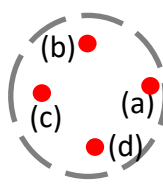0.001    0.004    0.001*    0.001*    0.100    0.23

(a)    (b)    (c)    (d)
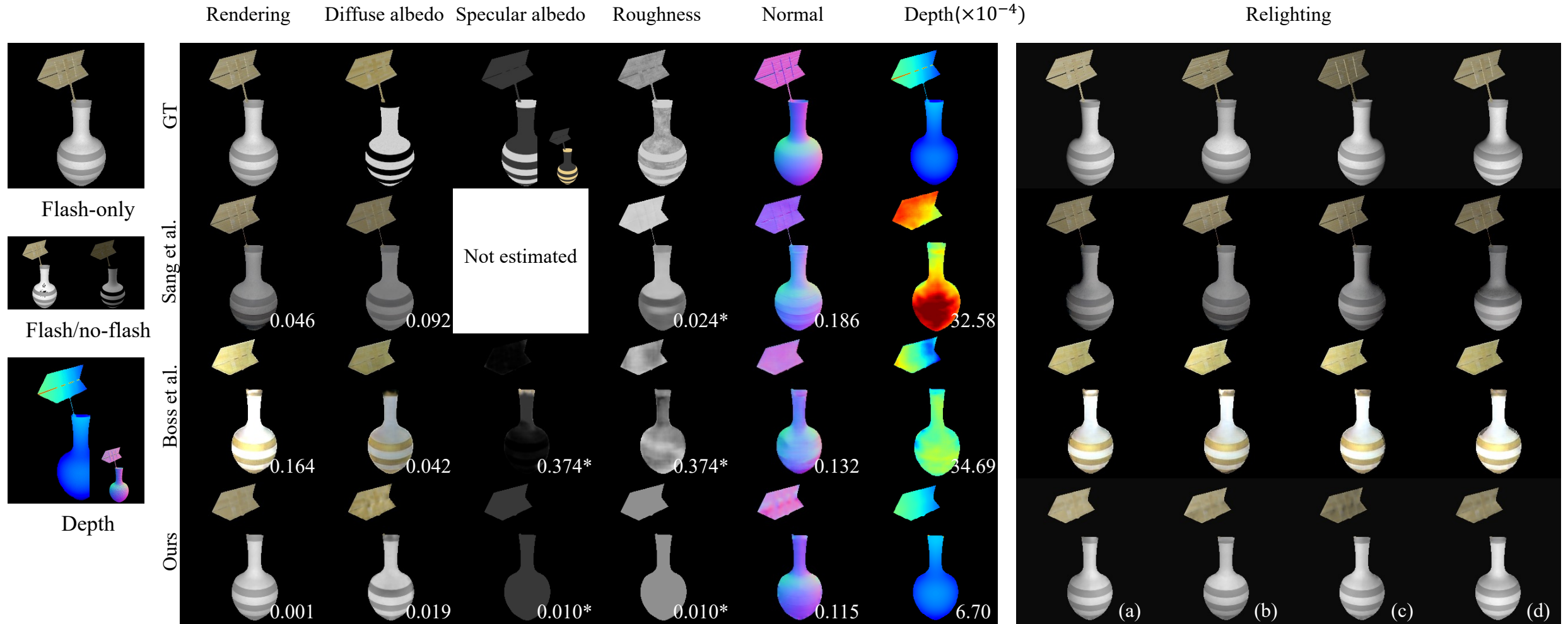
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

|  | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|
| GT | | | | | | | |
| Sang et al. | 0.046 | 0.092 | Not estimated | 0.024* | 0.186 | 32.58 | |
| Boss et al. | 0.164 | 0.042 | 0.374* | 0.374* | 0.132 | 34.69 | |
| Ours | 0.001 | 0.019 | 0.010* | 0.010* | 0.115 | 6.70 | (a) (b) (c) (d) |

Flash-only

Flash/no-flash

Depth

NB As Boss et al. model the Fresnel term from colored illumiNot estimatedtion, three-channel specular albedo is used for Boss et al. In contrast, Sang et al. and ours model monochromatic specular albedo from illumiNot estimatedtion, single-channel specular albedo is employed for both methods.
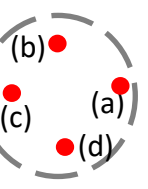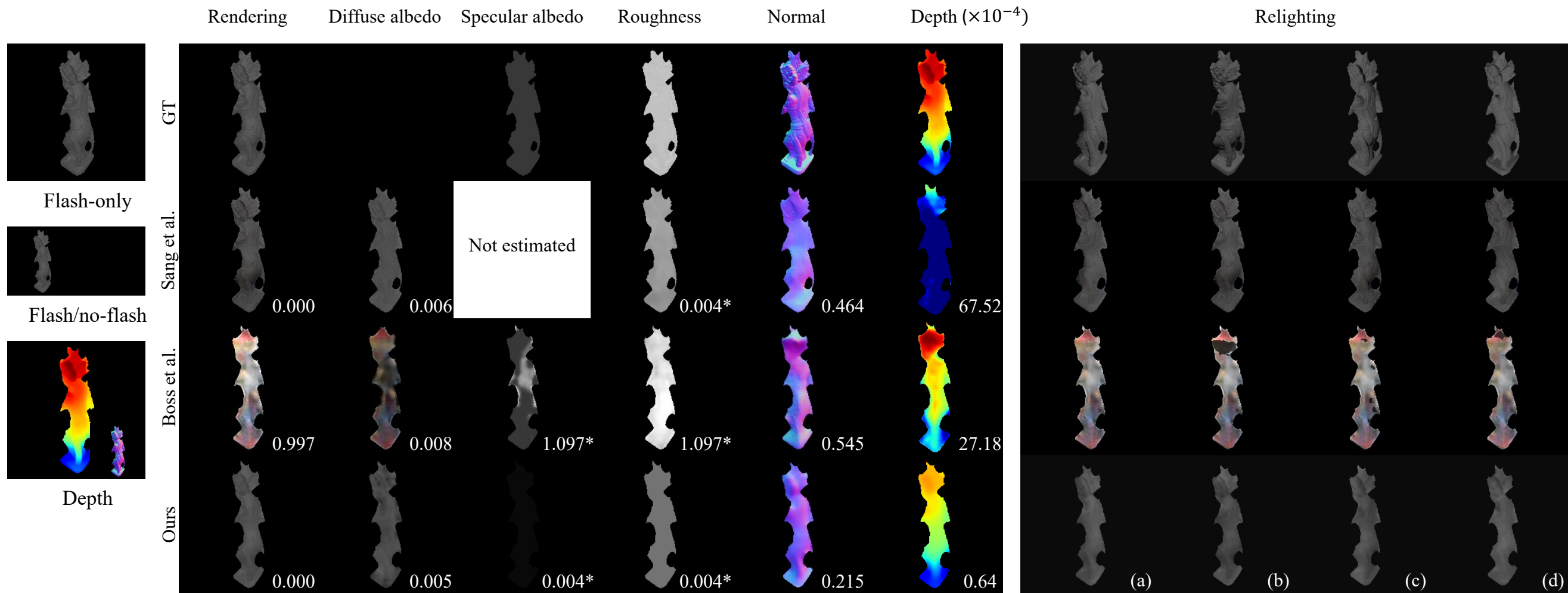
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

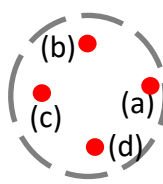Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting

Flash-only

Flash/no-flash

Depth

GT

Sang et al.

Not estimated

0.000    0.006    0.004*    0.464    67.52

Boss et al.

0.997    0.008    1.097*    1.097*    0.545    27.18

Ours

0.000    0.005    0.004*    0.004*    0.215    0.64

(a)    (b)    (c)    (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

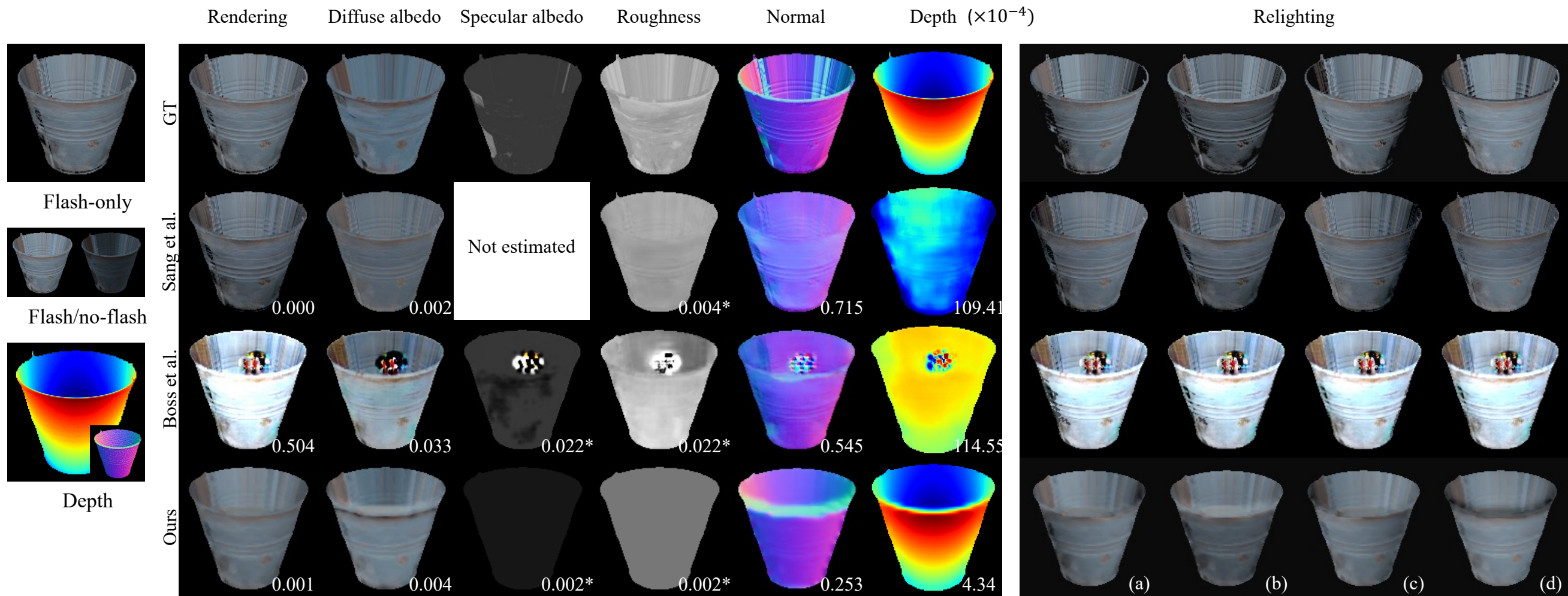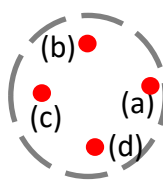| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth ($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

**GT**

**Sang et al.**
0.000  0.002  Not estimated  0.004*  0.715  109.41

**Boss et al.**
0.504  0.033  0.022*  0.022*  0.545  114.55

**Ours**
0.001  0.004  0.002*  0.002*  0.253  4.34
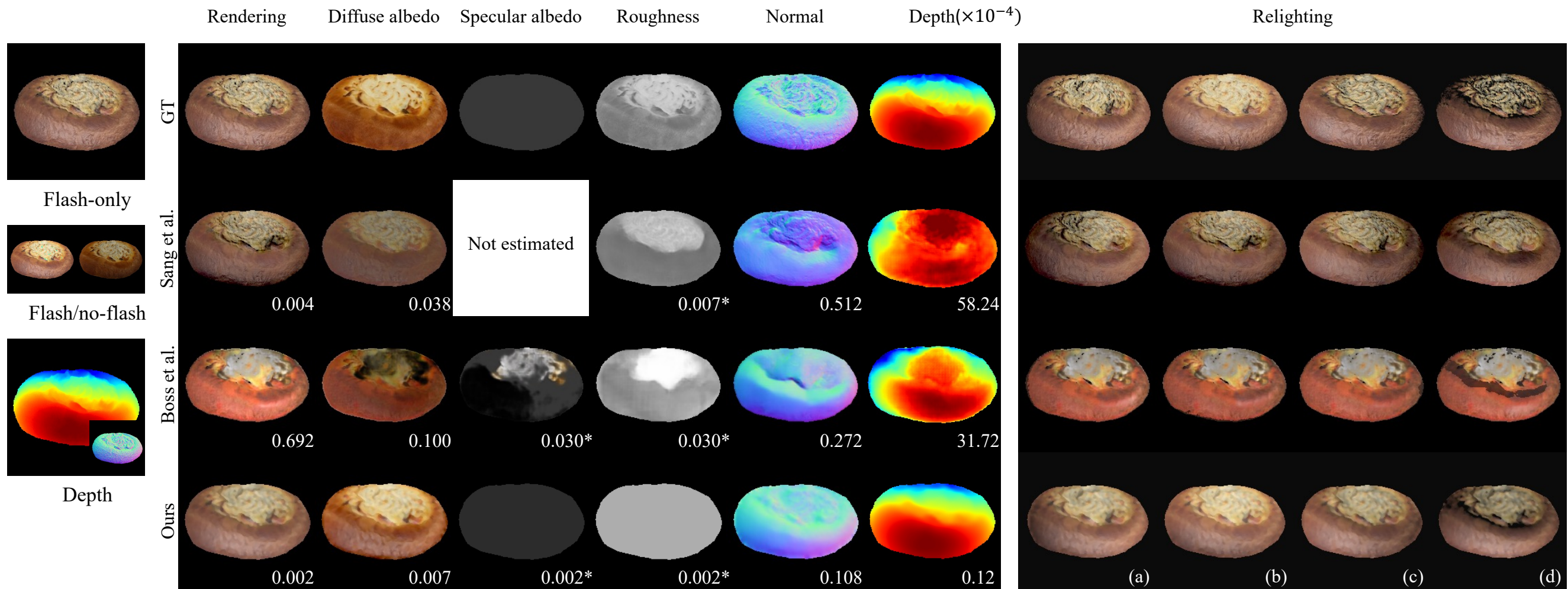
(a)  (b)  (c)  (d)
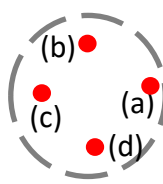
*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

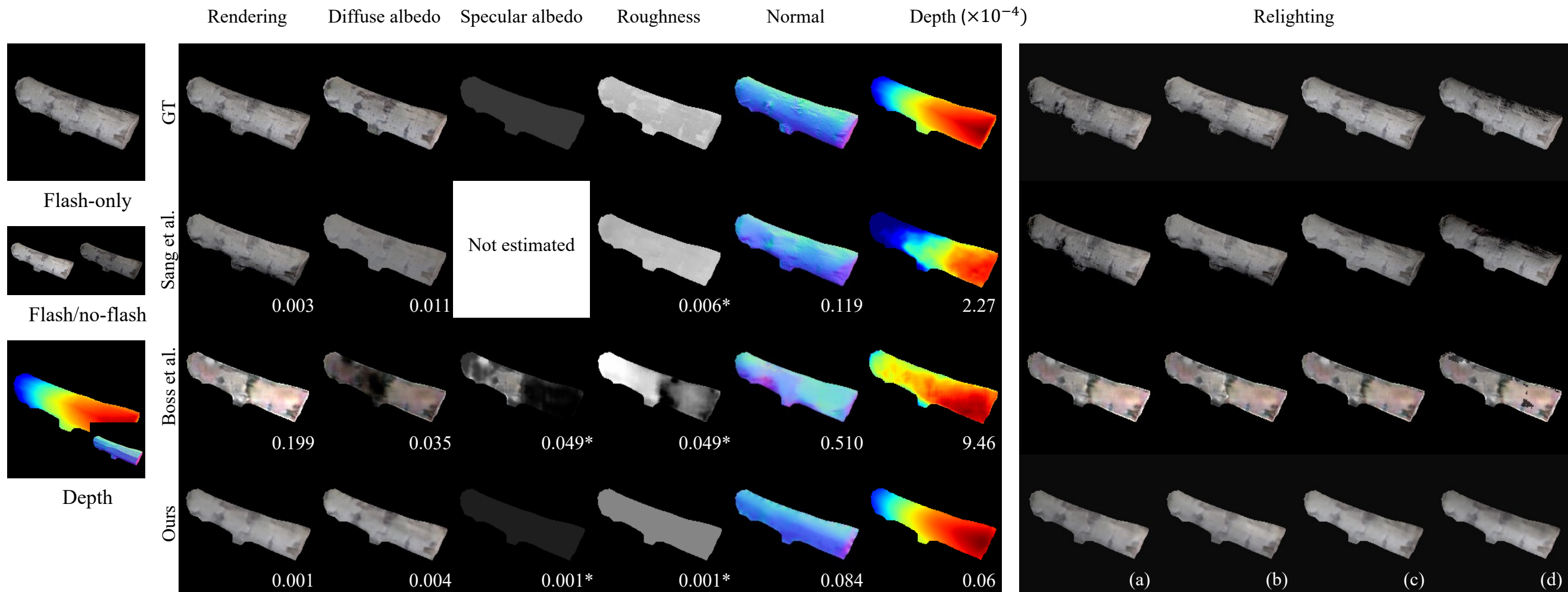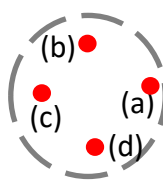|  | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth($\times 10^{-4}$) | Relighting |
|---|---|---|---|---|---|---|---|
| Flash-only | | | | | | | |
| Flash/no-flash | | | | | | | |
| Depth | | | | | | | |
| GT | | | | | | | |
| Sang et al. | 0.004 | 0.038 | Not estimated | 0.007* | 0.512 | 58.24 | |
| Boss et al. | 0.692 | 0.100 | 0.030* | 0.030* | 0.272 | 31.72 | |
| Ours | 0.002 | 0.007 | 0.002* | 0.002* | 0.108 | 0.12 | (a) (b) (c) (d) |

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.
0.003 | 0.011 | Not estimated | 0.006* | 0.119 | 2.27

Boss et al.
0.199 | 0.035 | 0.049* | 0.049* | 0.510 | 9.46
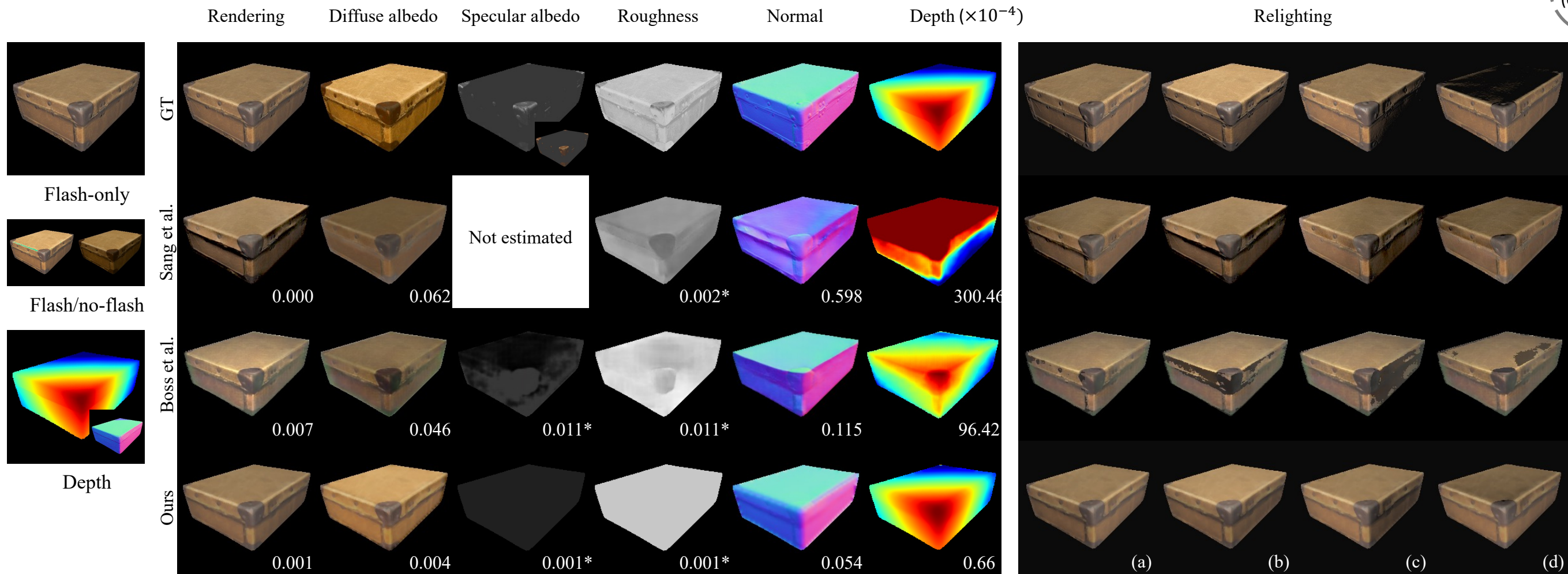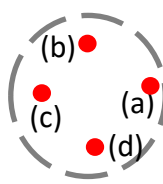
Ours
0.001 | 0.004 | 0.001* | 0.001* | 0.084 | 0.06

(a) (b) (c) (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

Flash-only

Flash/no-flash

Depth

GT

Sang et al.

Not estimated

0.000     0.062     0.002*     0.598     300.46

Boss et al.

0.007     0.046     0.011*     0.011*     0.115     96.42

Ours

0.001     0.004     0.001*     0.001*     0.054     0.66

(a)     (b)     (c)     (d)

NB As Boss et al. model the Fresnel term from colored illumiNot estimatedtion, three-channel specular albedo is used for Boss et al. In contrast, Sang et al. and ours model monochromatic specular albedo from illumiNot estimatedtion, single-channel specular albedo is employed for both methods.

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.

Flash-only

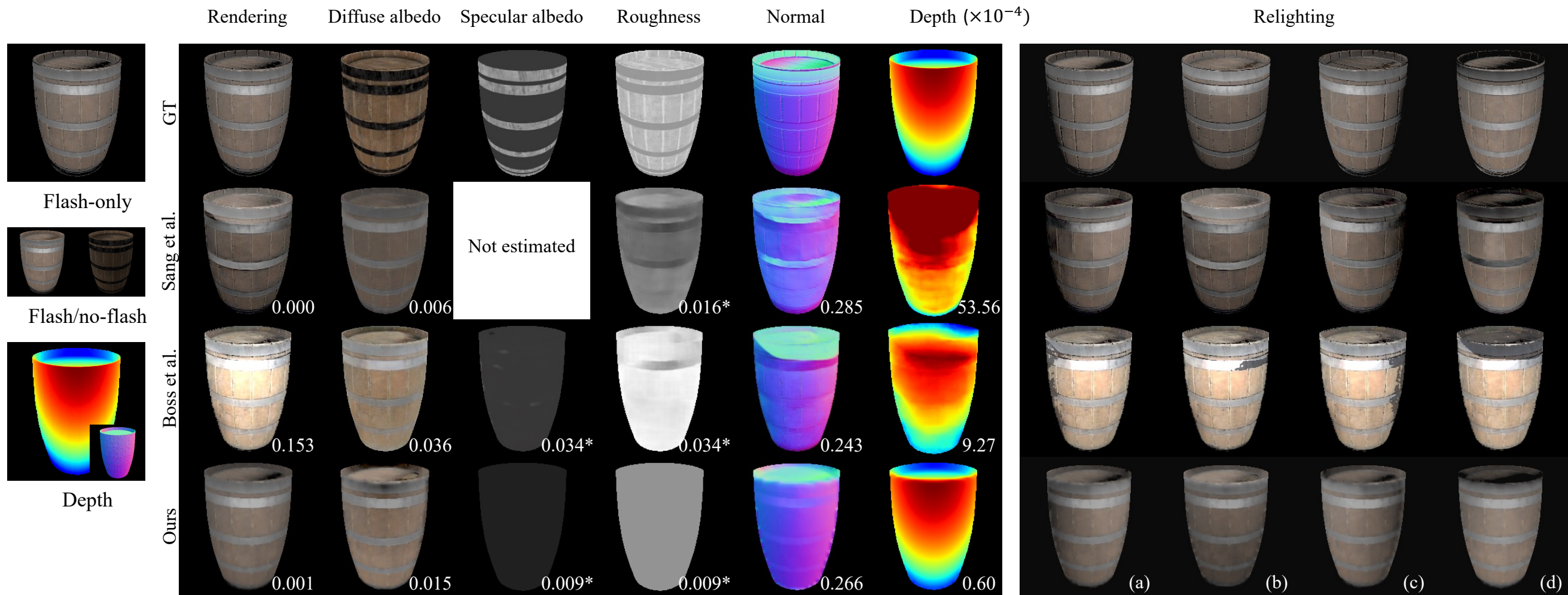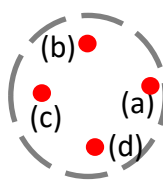Flash/no-flash

Depth

| | Rendering | Diffuse albedo | Specular albedo | Roughness | Normal | Depth (×10⁻⁴) | Relighting |
|---|---|---|---|---|---|---|---|

GT

Sang et al. — Not estimated — 0.000, 0.006, 0.016*, 0.285, 53.56

Boss et al. — 0.153, 0.036, 0.034*, 0.034*, 0.243, 9.27

Ours — 0.001, 0.015, 0.009*, 0.009*, 0.266, 0.60

(a) (b) (c) (d)

*: Owing to the model difference, the specular errors of albedo and roughness are calculated as an MSE of specular reflection.